MATERIALS PROCESSING | ANNUAL REPORT 2019

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On the Cover: Tyler Smith, The K/Sn/Si(111) surface reconstructed into a 2√3x2√3 charge-ordered Kagome lattice; the different colors represent four out-of-phase domains.

Advisory Committee

Established in early 2014, the Center for Materials Processing (CMP) Advisory Committee works with the CMP Director Claudia Rawn and Associate Director for Industrial Partnerships and Undergraduate Research Chris Wetteland regarding various areas of research that the CMP can advocate for and invest in for the future. The CMP leadership and the Advisory Committee are working together with the goal of bringing positive recognition to the CMP, the Tickle College of Engineering, and the University of Tennessee in areas related to materials processing. In early May 2018, the CMP Advisory Committee met to begin discussing how the CMP can provide a link between local industry and the University of Tennessee.

- **Dr. Sudarsanam Suresh Babu**
  UT/ORNL Governor's Chair of Advanced Manufacturing
  Professor–Mechanical, Aerospace and Biomedical Engineering
  Tickle College of Engineering
  University of Tennessee, Knoxville

- **Dr. William Dunne**
  Associate Dean for Research and Facilities
  Tickle College of Engineering
  University of Tennessee, Knoxville

- **Dr. Neal Evans**
  Industrial Consultant

- **Dr. Veerle Keppens**
  Professor and Head, Materials Science and Engineering
  Tickle College of Engineering
  University of Tennessee, Knoxville

- **Ms. Beth Matlock Snipes**
  Senior Materials Engineer
  Technology for Energy Corporation (TEC)

- **Mr. Trevor Toll**
  Lead Engineer – Materials Testing Laboratory
  Analysis and Measurement Services (AMS) Corporation

Mission Statement

The Center for Materials Processing supports teaching and conducting basic and applied research emphasizing relationships between processing, structure on various scales, and properties of all classes of materials. This support improves existing processing and synthesis techniques, developing new materials and technologies, transferring improvements to the applied sector, and equipping students to thrive in the broad field of materials science and engineering. The Center fosters interdisciplinary activities and establishes partnerships with industries and other institutions as appropriate.

Executive Summary

A key component of the CMP mission is the support of teaching and research in areas where materials processing plays a significant role. One of the cornerstones of materials science and engineering is the relationship between processing, structure on various scales, and the resultant electronic, magnetic, mechanical, optical, physical, and thermal properties. CMP funds are focused on supporting graduate and undergraduate students in several disciplines who are undertaking research in the various aspects of the processing, structure, and properties relationships. The CMP works as an advocate in the field of materials processing on many levels, including recruiting outstanding future students to study and work in materials processing related fields.

In addition to partially or fully supporting student assistantships through stipends, the CMP annually sponsors several poster sessions, participates in Materials Camp and the Tennessee Governor's Schools for Science and Engineering, and maintains key pieces of processing equipment for CMP supported students and industrial members to use. The CMP poster sessions are competitive, and students with posters that the judges recognize as the best are provided travel support to present their research externally and represent Tennessee at professional conferences. Current areas of specific interest to the CMP include additive manufacturing, characterization techniques, crystal growth, scintillation detectors, nuclear materials, and energy related materials. Another important component of the CMP mission is transferring improvements to the applied sector. To address technology transfer, the CMP offers Industrial Memberships, where membership funds can be used to support students and/or access to facilities.

CMP Staff

Claudia J. Rawn
CMP Director

Claudia Rawn has been director of the CMP since July 1, 2012. She received her BS in materials engineering from Virginia Polytechnic Institute and State University (Virginia Tech), her MS in chemistry from George Mason University, and her PhD in materials science and engineering from the University of Arizona. Prior to starting her graduate studies, she worked as a materials engineer in the Ceramics Division of the National Institute of Standards and Technology (NIST) performing experimental phase equilibria studies. After obtaining her PhD, she moved to Ljubljana, Slovenia, and became a postdoctoral research associate in the Ceramics Department at the "Jožef Stefan" Institute. Dr. Rawn returned to the United States and joined the Materials Science and Technology Division (MSTD) at Oak Ridge National Laboratory (ORNL) as a postdoctoral fellow of the Oak Ridge Associated Universities (ORAU). She was promoted to a research staff member and senior research staff member during her years at ORNL. In 2001, she became a joint faculty member with the Department of Materials Science and Engineering (MSE) at the University of Tennessee, Knoxville (UT). In December of 2013, Rawn retired from Oak Ridge National Laboratory and began concentrating all of her efforts at the University of Tennessee as an associate professor in the Materials Science and Engineering Department and director of the Center for Materials Processing. Since joining MSE, she has taught Introduction to Materials Science and Engineering, X-ray Diffraction and Structural Characterization of Materials, Principles of Ceramics, and is one of the original faculty associated with the Materials Processing course that was first introduced to MSE in 2005. For six years, she served as an instructor for the Governor's School for the Sciences and Engineering. She has served as the chair of the Undergraduate Affairs Committee for MSE, the Materials Advantage faculty advisor, and is on the University of Tennessee's Undergraduate Research Advisory Committee. Rawn's research interests include investigations of crystal structures, phase transitions, and thermophysical properties of a variety of materials using in-situ X-ray and neutron scattering methods. She has co-authored over 90 technical publications. Rawn is a fellow of ASM International and served on the United States National Committee for Crystallography from January 2009 to December 2015, serving as the secretary for three years. She is a member of several professional societies, including ASM International, the American Crystallographic Association, the Neutron Scattering Society of America, and the American Ceramic Society. She has also held several positions in the Executive Committee of the Oak Ridge Chapter of ASM (ORCASM), including chairperson. Under her direction, ORCASM started hosting their local Materials Camps. In 2010, ORCASM started hosting Teacher Materials Camps, and she has served as co-chair for both the student and teacher materials camps since they began. Rawn is the PI and site director of the UT site of the Manufacturing and Materials Joining Innovation Center (Ma^{2}JIC), funded by the National Science Foundation (NSF) and industrial memberships.

Chris Wetteland
Associate Director for Industrial Partnerships and Undergraduate Research

Chris Wetteland is currently serving as the associate director for industrial partnerships and undergraduate research for the Center for Materials Processing. His main appointment is with MSE as a senior lecturer. Wetteland received his BS in geology from Northeastern Illinois University, his MS in ceramics and materials engineering from Rutgers University, and his PhD in earth and planetary sciences at UT. Prior to joining MSE at UT, Wetteland worked at Los Alamos National Laboratory as a staff member from 1997-2006, where his research focused on ion beam analysis and radiation damage in materials. From 2010-2013, he was a research fellow at the University of Wisconsin-Madison, where he investigated accelerated aging of nuclear materials using particle accelerators. Wetteland presently teaches the laboratory coursework and advises senior design projects in MSE and serves as the faculty advisor of several student outreach organizations. His research interests include early solar system processes, radiation damage in nuclear materials, ceramic processing, solar energy, ion beam analysis, advanced manufacturing, and STEM outreach.

Karen Boyce
Financial Specialist

Karen Boyce is the financial specialist for the CMP, the Scintillation Materials Research Center (SMRC), the Reliability and Maintainability Center (RMC), and the Manufacturing and Materials Joining Innovation Center (Ma^{2}JIC) University of Tennessee, Knoxville, site. Boyce has been working within various university systems since 1995 and joined UT in June 2011.

Amber White
Administrative Specialist

Amber White has served as the administrative specialist for the CMP and the RMC since November 2016. Before joining the university, she spent five years in social work, specializing in low-income senior housing and fair housing regulation.

Students Supported by CMP

Christine Ajinjeru

What is your thesis topic?

Rheological evaluation and guidelines of high-performance amorphous thermoplastics and carbon fiber reinforced composites for additive manufacturing.

How is materials processing involved in your research?

My research uses materials processing to develop 3D printability guidelines for high-performance thermoplastics used in extrusion-based additive manufacturing (AM). Emerging applications in polymer AM motivate the need for production and development of new materials with a broader range of thermal and mechanical properties. Therefore, to advance rapid material screening across various extrusion-based AM platforms, my research uses materials processing to develop material screening methodologies to evaluate the extrudability of potential AM feedstocks as well as define their processing conditions to allow for a more rapid introduction of new materials to AM.

Provide an example of where the material/process/properties you are studying might find an application.

The BAAM (Big Area Additive Manufacturing) system is used for high-temperature tooling applications whose components are often designed and fabricated using various carbon fiber reinforced high-performance thermoplastics. The material characterization work that I do is instrumental in informing the deposition and bead formation process during extrusion of composite tools and molds on the BAAM system.

Bernadette Clark

What is your thesis topic?

Investigation of CH_4-CO_2 hydrate structure and dynamics with neutron scattering experiments and complementary simulations.

How is materials processing involved in your research?

I assembled a hydrate-synthesis lab, which is included in the JIAM ceramics laboratory, to synthesize gas hydrate powders at the required high pressure and low temperature conditions with CH_4 and CO_2 to be studied with neutron scattering.

Provide an example of where the material/process/properties you are studying might find an application.

I synthesize CH_4, CO_2, and mixed CH_4-CO_2 hydrates to perform structural studies with in situ total neutron scattering and dynamic studies with inelastic neutron scattering experiments. I use complimentary classical molecular dynamics simulations and density functional theory of these systems to complement neutron data analysis. These structural and thermodynamic studies will provide a comprehensive understanding of CO_2-CH_4 solid solutions, exchange kinetics, and implications on hydrate structure to better inform the production of CH_4 from natural hydrate deposits via CH_4-CO_2 exchange.

Kate Higgins

What is your thesis topic?

The growth of cation alloyed lead halide perovskite single crystals for ionizing radiation detection.

How is materials processing involved in your research?

My research funded by the CMP studied the ionic conductivity of binary sesquioxide mixtures, i.e., mixtures of M'_2O_3-M''_2O_3 (where M' and M'' represent distinct trivalent M^{3+} metal cations). I began my research fabricating a set of M'_2O_3-M''_2O_3 bixbyite solid solution samples using a variety of techniques that include: conventional dry ceramic processing; (1) wet chemical processing (sol-gel or Pechini methods), (2) hot press sintering, and (3) the cryochemical method of freeze drying. The fast ion transport of these materials is critical to several energy technologies, including batteries, fuel cells, separation membranes, and catalysts.

Amanda Haglund

What is your thesis topic?

My research is on the crystal growth of a class of semiconducting magnetic layered materials, with the structure of MXY_3, where M is a transition metal, X is P, Ge, or Si, and Y is S, Se, or Te. In addition to their growth, I am also measuring thermal conductivity and dielectric properties of each material.

How is materials processing involved in your research?

I grow single crystals from their base elements at high temperatures in tube furnaces.

Provide an example of where the material/process/properties you are studying might find an application.

Due to their unique layered nature combined with semiconducting and magnetic properties, the materials I am studying have recently gained interest as a resource for designing new transistor or memory storage technology. Moore's law, which says the number of transistors on an integrated chip doubles every two years, is beginning to fail with the semiconducting materials currently in use. The layered structure of the materials I am studying allows them to be thinned down to the atomic level while still maintaining semiconducting properties, which means transistor devices could be manufactured to smaller sizes than currently available.

Students Supported by CMP

Anna Hoffman

What is your thesis topic?

I am studying the effects of ambient aging and oxygen plasma processing on the electrical properties of thin film WSe_2 and $PdSe_2$.

How is materials processing involved in your research?

I use oxygen plasma processing to control the electrical properties of the thin film semiconductors I work with. High energy oxygen radicals oxidize the top layer of the semiconductor into a metal oxide, which significantly changes electrical behavior without structural damage. Through mask technology, I am able to precisely control where the plasma is exposed to the material, thus allowing the creation of complex devices with a single processing step.

Provide an example of where the material/process/properties you are studying might find an application.

The materials I work with are used in electronics. Due to their extremely small scale (a sample one nanometer thick is easily achievable), they have the potential to reduce electrical components to a fraction of their current size. This means faster, lighter, smaller devices (possibly even nanosized) with increased power. Possible applications include phones that have the processing power of desktop computers and gas sensors that fit on your fingertip.

Yongtao Liu

How is materials processing involved in your research?

The focus of my research is to explore ion migration and ferroic behavior in metal halide perovskites (MHPs) to unveil the true effects of ion migration and ferroic state on MHP-based optoelectronics. Despite the impressive photovoltaic performance delivered by MHPs in the past decade, poor stability creates a huge barrier in the practical applications of MHP solar cells. My research on understanding the effects of ion migration and ferroic state on optoelectronic properties of MHPs will be useful for improving the stability of MHP solar cells.

Matt Loyd

What is your thesis topic?

My dissertation is titled “Investigation of Environmental Degradation in Plastic Scintillators” and focuses on “fogging”, a phenomenon where plastic scintillators will absorb moisture at high temperatures and humidities and become opaque upon cooling.

How is materials processing involved in your research?

My research focuses on producing and characterizing scintillation materials for national security applications. For producing novel scintillators, we use the Bridgman technique of single crystal growth. It is important to control the ampoule geometry, furnace parameters, and growth speed in order to produce a high quality, single crystal. Additionally, I have worked with aging of plastic scintillators. Although we do not produce them here, we have corresponded closely with an industry partner, Eljen Technology.

Provide an example of where the material/process/properties you are studying might find an application.

My research is very specific and is being pursued due to its implications in national security. Because fogging requires that plastic scintillators deployed in certain environments be replaced, it is important that we understand and can prevent fogging in the next generation of plastic scintillators.

Brianna Musico

What is your thesis topic?

I am performing a study on the synthesis and characterization of a series of multi-component high entropy oxide samples with both spinel and perovskite structures.

How is materials processing involved in your research?

My research is dependent on materials processing as it is very dependent on sample creation via the solid-state synthesis method. I am focusing on the synthesis and characterization of multicomponent ceramics termed high-entropy oxides. This means a lot of time is spent in combining 5 or more elemental oxides to see what forms a single phase and how the properties (electronic/magnetic/structural) change with substitutions in the composition.

Provide an example of where the material/process/properties you are studying might find an application.

I am on the true basic science side of research at the current stage of this new class of materials, so the applications of some of the materials I work with are yet to be determined. The goal is to work towards engineering new ceramic materials by applying the concept of entropy stabilization to complex oxides.

Students Supported by CMP

Christopher Ostrouchov

Chris Ostrouchov is a PhD candidate in MSE working under the direction of William Weber. Ostroucov received his bachelor's degree in applied mathematics with a minor in computer science from Clemson University. Ostrouchov's broad research interests include the intersection of computation, statistics, and materials science. His undergraduate experiences taught him the importance of testing, reproducibility, and documentation to scientific codes.

Ostrouchov's research focuses on interatomic- potential development for molecular dynamics and applies it to advanced optimization methods and required workflow automation of codes such as LAMMPS, VASP, and SIESTA. These interatomic potentials are especially important in the field of radiation materials because current potentials are not suitable for non-equilibrium conditions.

Ostrouchov has helped teach several graduate thermodynamics courses and a computational material science class focusing on density functional theory. In 2017 he received the "Graduate Student Award for Excellence in Teaching" from MSE. Ostrouchov was formerly the president of the UT Materials Research Society, leading outreach events that educated others about material science.

Cody Pack

What is your thesis topic?

3D printing of hybrid core-shell architectures via direct-write additive manufacturing.

How is materials processing involved in your research?

My research lies in direct write (DW) additive manufacturing, more widely known as 3D printing. Additive manufacturing is a unique materials processing route in which components are built in a layer-by-layer fashion that enables the production of novel architectures and multi-material hybrid structures that cannot be produced by traditional processing routes. More specifically, my research lies in the processing and characterization of novel core-shell architectures via DW 3D printing.

Provide an example of where the material/process/properties you are studying might find an application.

Working with a material system of epoxy-based inks consisting of a syntactic foam core surrounded by a carbon fiber reinforced ink shell, lightweight and stiff core-shell structures can be produced via direct write 3D printing. These structures exhibit superior properties to monolithic materials, showing potential application for use in improved structural components such as lightweight cellular structures.

Brandon Shaver

What is your thesis topic?

I am conducting experiments evaluating uranium dioxide for use as a material in solid-state direct-conversion neutron detection. In addition to materials processing, neutron irradiation studies have been performed on bulk and thin film samples.

How is materials processing involved in your research?

My research involves evaluating UO_2 as a potential semiconductor for use in solid-state neutron detectors. The required material properties of uranium oxides do not inherently meet the goals required for these devices. Utilizing different processing methods can improve these properties by the introduction of dopant materials to alter the microstructure and electrical properties.

Provide an example of where the material/process/properties you are studying might find an application.

The current goal is to improve the properties of the candidate material's to match the required electrical properties of solid-state neutron detectors. This requires increasing the electrical resistivity and carrier mobility and depends on utilizing various processing methods.

Tyler Smith

What is your thesis topic?

"Exploring electronic instabilities in triangular lattices through multiple doping schemes: Mott insulators and Rashba systems"

How is materials processing involved in your research?

The research is primarily focused on adsorbate doping of correlated electronic systems on silicon platforms, potentially driving these surfaces into a superconductive state. This is performed in-situ, where these surfaces are decorated with electron-donating alkalides or electron-accepting molecules.

Provide an example of where the material/process/properties you are studying might find an application.

The possibility of attaining superconductivity on a silicon platform is highly lucrative as it is an abundant material in modern devices, with a potential application into new technologies such as quantum computing.

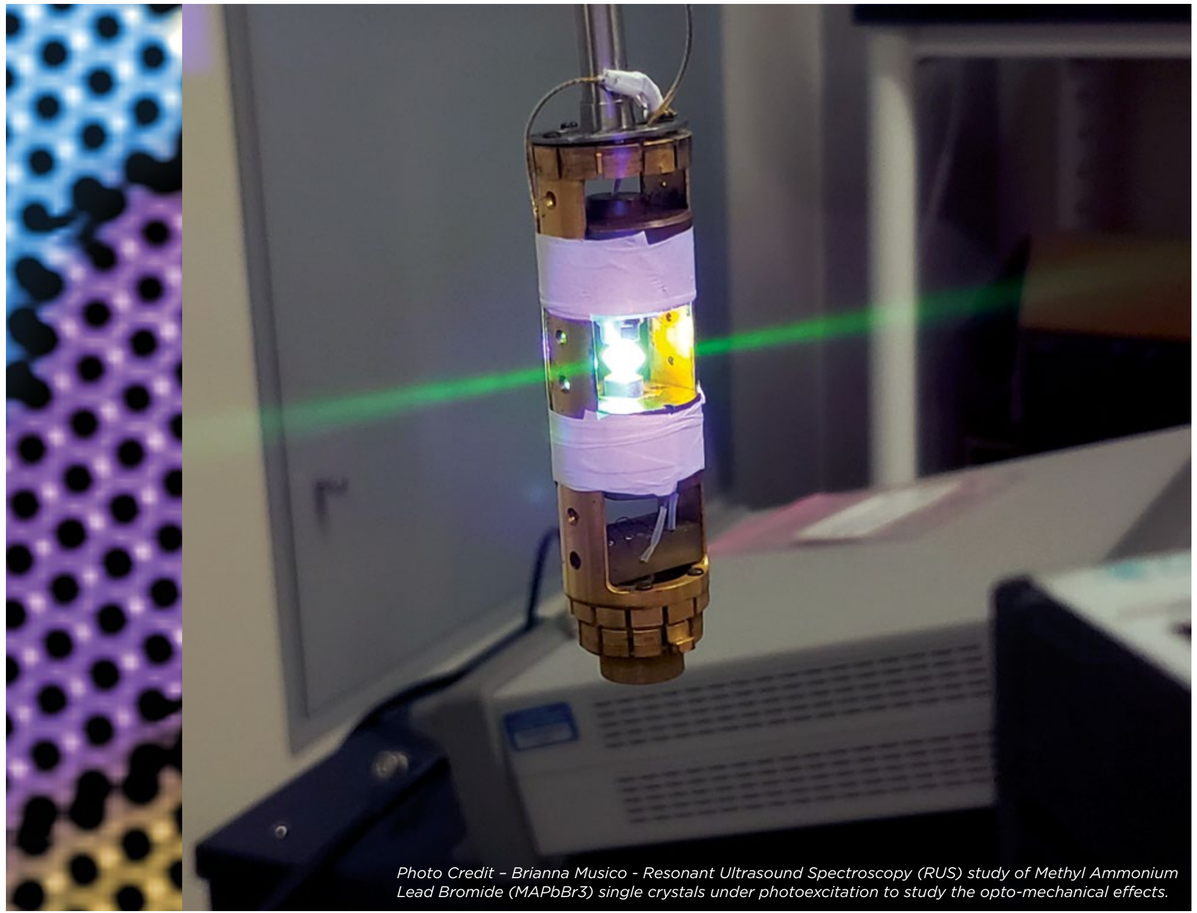


Photo Credit – Brianna Musico - Resonant Ultrasound Spectroscopy (RUS) study of Methyl Ammonium Lead Bromide (MAPbBr3) single crystals under photoexcitation to study the opto-mechanical effects.

Students Supported by CMP

Youxiong Ye

What is your thesis topic?

As a new concept of alloy system, high-entropy alloys (HEAs) abandon the "base-element" idea and adopt a mixture of multiple principal elements in an equimolar or near-equimolar ratio to form multi-component alloys. Mechanical behavior of HEAs is one of the major topics and is yet to be explored. My thesis topic is to provide the fundamental understanding of mechanical, tribological behavior at small scales and local lattice structure of BCC structured TiZrHfNb-HEAs.

How is materials processing involved in your research?

My main research topic is to investigate mechanical behavior at small scales of high-entropy alloys. We used arc-melting and drop-casting to fabricate the alloys. Hot rolling, cold rolling, and heat treatment (including homogenization, annealing, aging, etc.) were performed to control the microstructure of the alloys. Mechanical tests and microstructure characterization were then carried out to build the relation of processing-microstructure-mechanical properties of the alloys. One of my other research projects is to study the energy and keyhole coupled mechanism in laser additive manufacturing (AM) of high-entropy alloys.

Provide an example of where the material/process/properties you are studying might find an application.

One of my projects is to study the tensile creep behavior of Mg-Gd binary alloy. Traditionally, the precipitate-free zone (PFZ) is treated as a blank region with weak strength. However, in this project, we employed hot rolling, solid solution treatment and then artificial aging to introduce a high density of PFZs along grain boundaries. We unexpectedly found that the high density PFZs can relieve local stress concentration and catalyze a homogeneous stress distribution, thus enhance creep resistance.

Robert Minneci

What is your thesis topic?

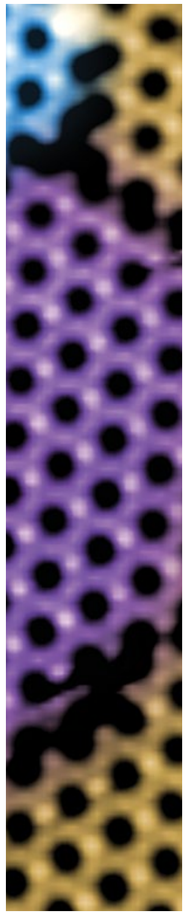
My thesis topic is on characterizing a high temperature copper alloy called GRCop-84 that NASA is developing for use in its future space craft with additive manufacturing. My efforts are focused on adding to the characterization efforts that NASA has already done by using neutron diffraction techniques to learn information unobtainable otherwise.

How is materials processing involved in your research?.

Materials processing is intrinsic to my research as NASA is currently applying additive manufacturing to GRCop-84, which has many unknowns with regards to final microstructures, properties and performance. GRCop-84 was developed in the 80's but has only been applied to additive manufacturing for the last few years, and additive manufacturing creates very unique microstructures with properties equal to or better than traditionally fabricated hardware. Additive manufacturing also allows for more complex geometries that greatly improve performance in high temperature applications.

Provide an example of where the material/process/properties you are studying might find an application.

GRCop-84 has excellent high temperature properties and is best served in applications as a heat conductor and structural component. NASA is developing it for the combustion chamber liners of rockets, but it can be applied to welding equipment, reactor walls, aerospace hardware and other similar high heat flux applications.



Students Supported by CMP

Katie Browning

How is materials processing involved in your research?

My current research focuses on a better understanding of polymeric binders used in composite electrodes and their effect on the performance of next generation silicon anodes. I utilize in situ neutron reflectometry to better understand structures of buried interfaces within batteries and surface-sensitive techniques, such as x-ray photoelectron spectroscopy, to determine the reaction chemistries occurring at those interfaces.

John Bohling

What is your thesis topic?

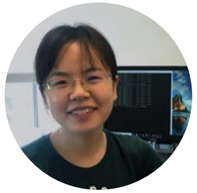
My dissertation research topic is focused on further understanding the creep behavior in 9Cr-1Mo-VNb (Grade 91) steels, specifically the occurrence of creep damage in the fine-grain weld heat-affected zone (FGHAZ or "Type IV" region).

How is materials processing involved in your research?

My research is concerned with the changes that occur in metals as a result of welding and heat treatment, primarily focused on carbon and low-alloy steels. The choice of welding process, specific welding parameters, and heat treatment conditions can dramatically alter the properties (such as strength and corrosion resistance) of a given steel. Thus, understanding the effects of welding on material properties is important to enable successful fabrication of steel structures and to either prevent or mitigate welding-related problems.

Provide an example of where the material/process/properties you are studying might find an application.

Cr-Mo steels are widely used in the power generation and petrochemical industries (e.g,. for steam piping in power plants. In welded Cr-Mo steel steam piping, the high temperature conditions lead to creep void formation in specific regions such as the FGHAZ or the weld deposit, eventually resulting in failure. Understanding how creep damage occurs in Cr-Mo steel weldments is important for determining when existing steam piping must be repaired or replaced and also for developing Cr-Mo steels with improved creep properties that enable power plants to operate at higher temperatures (and thus higher efficiencies).



Xue Wang

What is your thesis topic?

Predictive micromechanical modeling of processing and failure behavior in advanced materials joining techniques.

How is materials processing involved in your research?.

My research mainly focuses on the modeling of the friction stir welding (FSW) process that, when compared with traditional fusion welding, shows several superiorities and has been widely used to join low melting temperature materials such as Al alloys. The quality of FSW process mainly depends on the processing control. For my study, the main objective is to quantify the novel material processing technique friction stir welding through an integrated computational material engineering (ICME) approach.

Provide an example of where the material/process/properties you are studying might find an application.

Friction stir welding has been applied in many fields such as aerospace, automotive and railways. Numerical simulation could help to understand the underlying mechanism of FSW, predict the highly nonuniform property and microstructure of the weldment, and optimize the operation parameter to improve the weldment quality.

Thesis/Dissertation Titles

Katie Browning
MS – Summer 2019

Title: The Study of Polymeric Binders and Their Role in Concomitant Solid-Electrolyte Interphase Formation on Silicon Anodes

Advisor: Claudia Rawn

Current Employer: PhD program at Vanderbilt

Shuying Chen
PhD – Spring 2019

Title: Microstructural Characterization and Mechanical Behaviors of High Entropy Alloys at Room and Elevated Temperature

Advisor: Peter Liaw

Current Employer: University of Pittsburgh

Alex Hanson
PhD – Spring 2019

Title: The Response of Ti_3SiC_2 to Ion Energy Dissipation During Energetic Irradiations at Different Temperatures

Advisor: William Weber

Current Employer: Idaho National Laboratory

John Salasin
PhD - Summer 2018

Title: Synthesis and Formation Studies of C12A7: A Functional Material

Advisor: Claudia Rawn

Current Employer: BWXT, Lynchburgh, VA

Jeremy Tisdale
PhD – Fall 2018

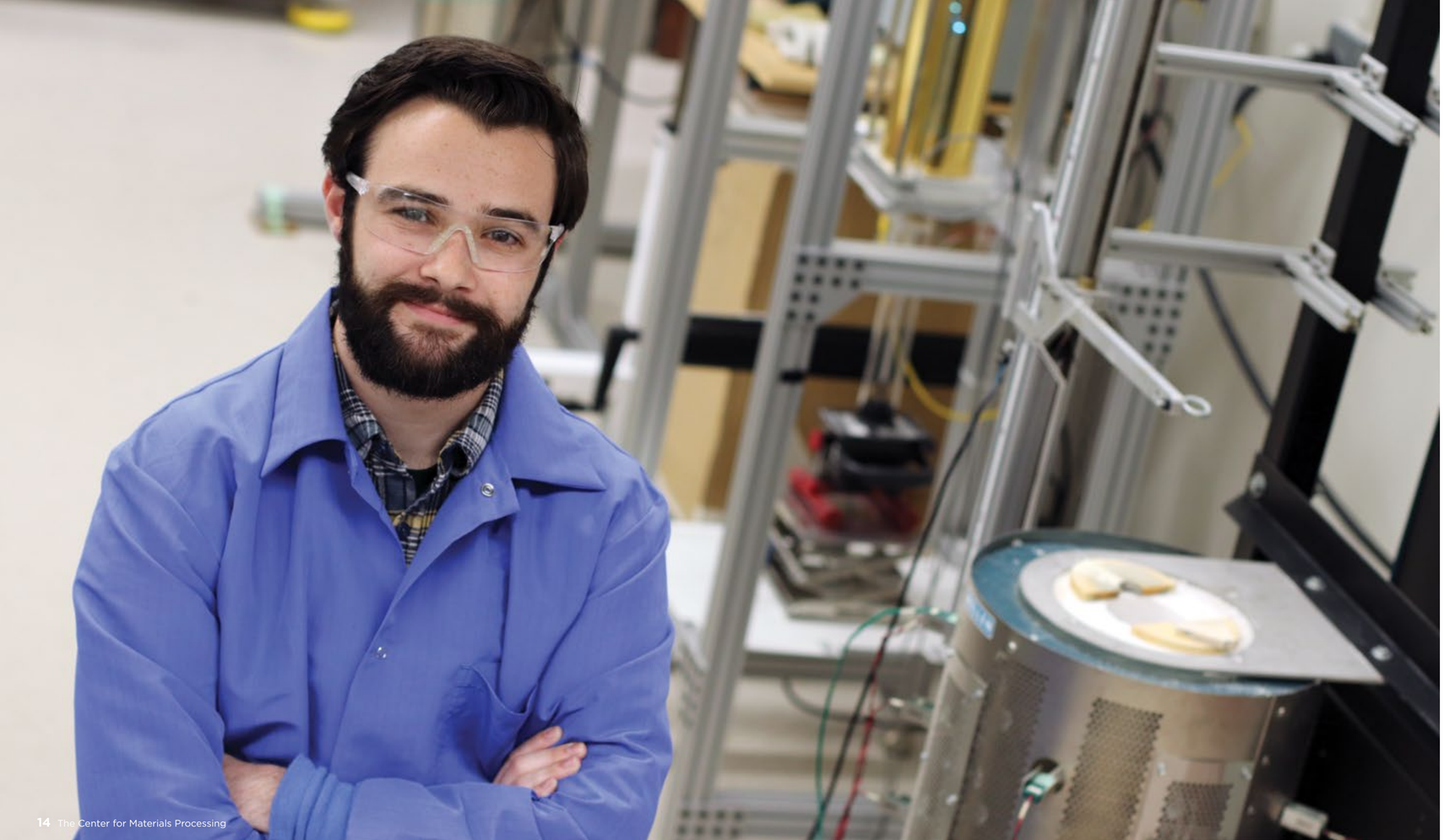
Title: Development of Organometallic Hybrid Perovskite Single Crystals Towards Radiation Sensing and Optoelectronic Applications

Advisor: Bin Hu

Current Employer: Los Alamos National Laboratory

Joshua Tharpe
Non-thesis Masters - Summer 2018

Current Employer: Union County High School



Ian Greeley: Finding Opportunity—Creating it for Others

By Meghan McDonald. Photography by Randall Brown.

Ian Greeley discovered materials science as a high school student attending summer programs led by Associate Professor and CMP Director Claudia Rawn and Senior Lecturer Chris Wetteland. Now, as a senior in the Department of Materials Science and Engineering, he's conducting his own research in novel single-crystal scintillators—and creating opportunities for more students to get hands-on research experience in the world of materials.

What attracted Greeley to MSE at UT were the many research opportunities that awaited him in his sophomore year.

"When I was looking at colleges, one of the draws for different people was 'It's a big college, there are a lot of different opportunities!' or 'It's a small college, it's personal!' At UT, with MSE, I feel like I've gotten the best of both," Greeley said. "UT is a large, public research university, but MSE is relatively small, and you get to know a lot of your professors and classmates."

For the past two years, Greeley has worked at UT's Scintillation Materials Research Center (SMRC) under the mentorship of Director Charles Melcher and Research Assistant Professor Yuntao Wu. Scintillator materials absorb high-energy radiation (like gamma rays or X-rays) and then release the energy as visible light. Photo detectors can translate that light into electrical pulses that characterize the radiation source.

Greeley first toured SMRC when he attended the Governor's School for the Sciences and Engineering, which is held on campus each year. He became interested in the nuclear security applications of scintillators—they are used to detect radioactive materials illegally taken into or out of national labs, as well as national borders. National security and medical imaging are two of the most important, but by no means the only, applications for scintillation technology.

With Wu, Greeley had been studying, among other things, how to improve scintillator performance through different customization methods.

"When we're trying out different ways to improve scintillators through changing the composition," Greeley said, "there are different ways to tailor the properties. One way may work for one class of scintillators, another may not. Now I'm doing my own project. I'm looking at how to optimize the collection of light from the crystal...through different sample preparations and reflector set-ups."

With support from both SMRC and UT's Center for Materials Processing, Greeley holds two positions: undergraduate research assistant and teaching assistant for the Cook Grand Challenge Honors program. This Eagle Scout is also taking his interest in research beyond the lab and the college classroom.

Greeley worked with Wetteland and several other students to propose and develop a hands-on experience for area STEM Scouts, a new co-ed program from the Boy Scouts of America. They piloted the week-long camp this past summer.

"We taught them how to do some computer-aided design and use a 3D printer," Greeley explained. "Then we had them 3D print space shuttles (based on the Cub Scouts' space derby) and race the shuttles they'd made. We hope it will encourage other universities to do similar things since STEM Scouts is on the rise right now," Greeley said.

Going forward, Greeley intends on going to graduate school, although he may take a gap year first to hone in on a research area.

"As of right now, I'm most interested in either [continuing with scintillators], or energy storage, or even biomaterials," he said. Whichever he chooses, his opportunities for research and outreach will only grow.

Brianna Musico: Dedicated to Discovery

By Meghan McDonald. Photography by Randall Brown.

"I was always involved in sports," explained **Brianna Musicó**, a fourth-year doctoral student in the Department of Materials Science and Engineering. "I was a competitive gymnast for a long time. That's how I became interested in materials science."

By asking why the bar she swung on didn't break, by wondering why the leotard she wore was so stretchy, she launched herself down a path of discovery in what she describes as the "lesser known engineering field that applies to all the others." With a year and a half left in her PhD, she's focused on her research in high-entropy oxides (HEOs) and excited to get more people involved in materials science.

Musicó completed her bachelor's at UT in 2016 and immediately began graduate school. She started working with HEOs at the encouragement of her advisor, Department Head Veerle Keppens, and a connection at Oak Ridge National Laboratory.

"This is a newer class of materials with a lot of room for discovery and further understanding, making it a fun field for me!" Musicó said. "This gives me the freedom to come up with novel compositions and explore the true basic science side of research."

Right now, she's specifically looking at the magnetic properties of new HEO materials. Each material she makes is composed of up to ten different elements.

"I do a lot of ceramic processing. We've got the periodic table to work with," she said. "You've got to sit there and play the game of what goes with what, what can work, what doesn't...models and theories haven't caught up to systems that are this complex."

CMP has been an important source of support for Musicó's research, which earned her acceptance in 2018 to the National School on Neutron and X-Ray Scattering. Musicó also appreciates the CMP's emphasis on outreach.

"If I hadn't done some weird googling," she said, "I wouldn't have heard of materials science. A lot of other people I know didn't hear about it 'till they were in college, or even until their graduate career."

To help change this trend, Musicó teaches, mentors, and serves as president of the Materials Research Society chapter at UT. In that capacity, she puts her energy toward growing the chapter and generating community interest.

This past June, she served her fourth year as a teaching assistant at the Governor's School for the Sciences and Engineering. This year, Musicó said, "we tried to tie in more of the history of materials and what people used in different eras, like colors."

It was the perfect connection back to the world around her. Musicó's mother, now an eighth-grade science teacher, previously specialized in art restoration.

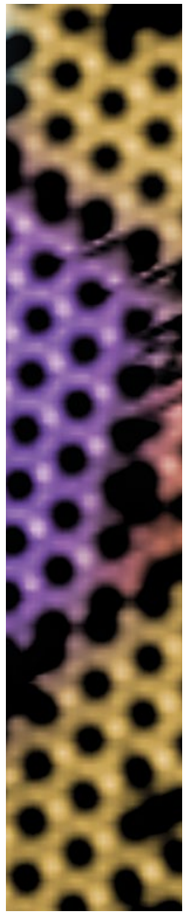
"She worked with historical pieces, and you would have to try to match the tones that you can't produce the same way now." Knowledge of how to make the original pigment may have been lost, or the original pigments contained ingredients like lead.

"I was able to pull things out of my mom's old boxes and talk about the history of blue to the students," she said. "You had the Egyptian blue, and you had copper that oxidizes and forms the blue crystal they would grind up."

This angle was a new way for Musicó to share her excitement about materials science—which applies to all kinds of things that aren't science.

"This is my family where I see it. It's all around you. That's what makes it interesting!"

Through her dedication to the field, Musicó is able to help others discover this connection between materials science and what's around them.



Building the Team for Success with ARC

By Meghan McDonald. Photography by Shawn Poynter.

ARC Automotive has found a new reason to bleed orange thanks to students in the Department of Materials Science and Engineering. The inflator manufacturing company operates in four countries on three continents, but its headquarters and R&D center are located just minutes from UT. Through a partnership quarterbacked by Senior Lecturer Chris Wetteland, ARC and MSE students are helping each other find opportunities for growth.

The initial relationship started with Wetteland, the associate director for industrial partnerships and undergraduate research at CMP, and Tom Graumann, now director of talent acquisition and leadership development for ARC. Three years ago, Graumann began meeting with MSE students to critique resumes and hold a Q&A session.

“I was really impressed with the students, materials, the labs that I saw, and the equipment they were using,” Graumann said.

When Dan Holloway came on as ARC’s global VP for human resources and safety last year, he joined Graumann and Wetteland at the annual event.

“It’s a learning experience for us to speak with students, too,” he said. “Employers say, ‘We need experience.’ But you talk to these students and see the capability and intellect they have, and you’d think employers would realize, maybe experience at the work place is not that important. The projects they’re working on in college right now are amazing.”

Graumann agrees. “Thinking about some of the students we’ve met,” he said, “they not only have the intellect, they’ve got the personality to go with it, and the experience to go with that. They’re people we’d love to have on our team.” And, he added, “They’re in my backyard.”

Earlier this year, Graumann and Holloway introduced ARC’s VP of engineering Brian Pitstick to Wetteland. Tours of MSE’s facilities followed, along with meetings with students. This move resulted in collaboration between MSE and the product engineering group at ARC.

“ARC is providing real-life work for students there,” Graumann said, “and we receive the data.”

Holloway summarized the benefits for ARC: “One, to have a feeder system for talented engineers for our R&D center. Then to work hand-in-hand on joint projects. Three, they have technology not every company has because of the cost. By working together, we’re able to use that equipment and it helps with our product development.”

Holloway also connects this partnership with ARC’s goal to be one of the best places to work in Knoxville.

“Thirty years ago, manufacturing was the place to be. It’s not now,” he said. “We want to change that way of thinking…by hiring the best people, retaining them, and growing them in the company.”

> **“[It’s] a feeder system for talented engineers for our R&D center…they have technology not every company has because of the cost. By working together, we’re able to use that equipment and it helps with our product development.”**
>
> — Dan Holloway, ARC global VP for human resources and safety

Whether or not students ever work for ARC, Graumann and Holloway are a resource for them.

“We like to give back and support the local community and students,” Holloway said. “It’s good to connect with someone who’s been in the business a long time.”

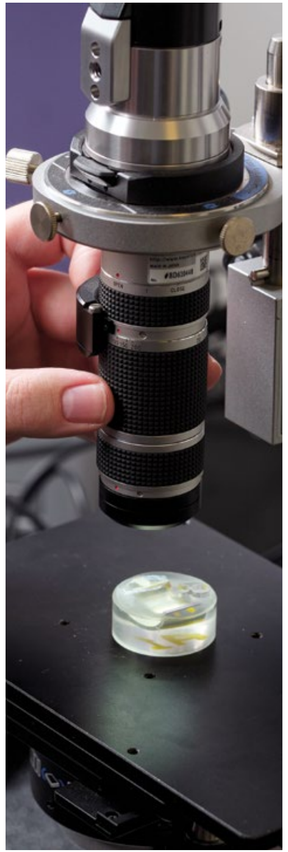
“We love to help,” Graumann added. “We love the students, the materials science group, and Chris Wetteland.”

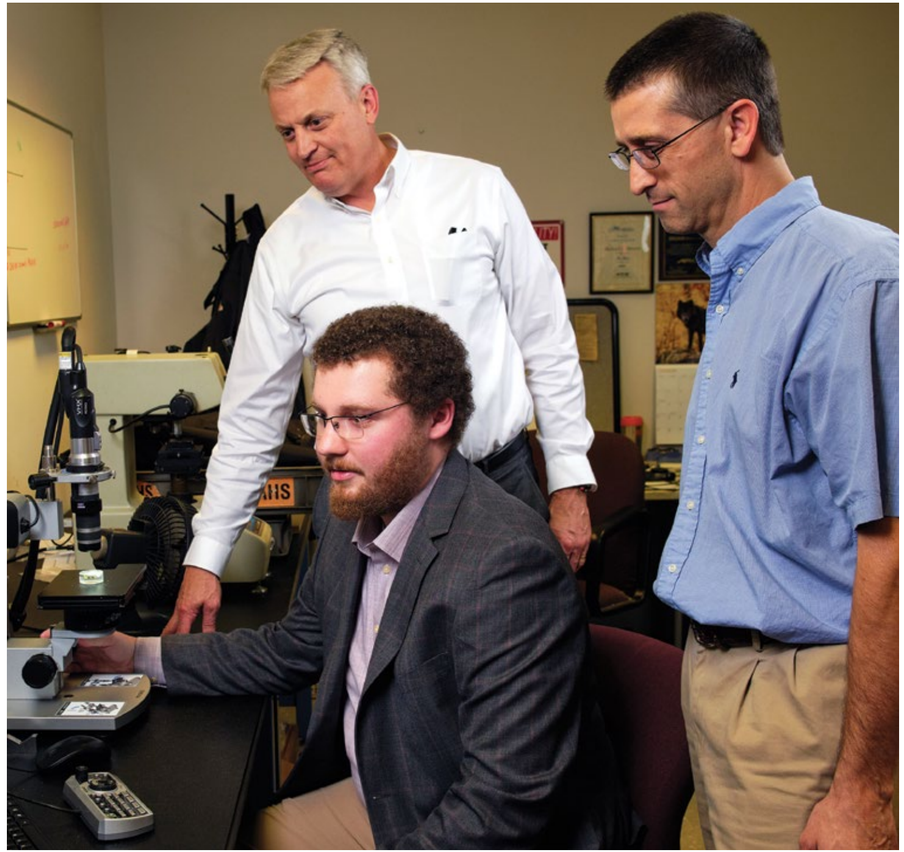
The passion Graumann and Holloway have for this partnership comes through loud and clear.

“My advice to other employers,” Holloway said, “is if you’re looking at other schools that are traditionally the ‘best engineering schools,’ don’t overlook Tennessee. There are some really talented students right here.”

Graumann put it more emphatically: “Every company in Knoxville–every company–could benefit from the materials science group at UT. But those companies have to have passion. They’ve got to see the value like we see the value.”

After all, he said, “These kids are game changers.”





Program Overview and Accomplishments

In FY19, approximately 85% of the appropriation expenditures for the Center for Materials Processing (CMP) were for supporting personnel, with about half of salary expenditures used to support graduate and undergraduate assistantships. Undergraduate research and experiential learning are becoming increasingly important for students to include on their transcripts and resumes. The CMP was an early supporter of undergraduate research and continues to expand resources in this critical area. In FY19, the CMP either fully or partially supported 14 graduate and 38 undergraduate students performing materials processing research. CMP supported students were involved in a vast array of research topics ranging from preparing functionally graded ceramic to materials for radiation sensing. To read more about student research, see pages 4-13. CMP sponsored research was highlighted in 23 publications, posters at minor and major MSE professional conferences, and earned one journal cover, the inaugural issue of Ceramics, an open access journal from MPDI.

In January of 2018, the CMP began a competitive process for graduate students to be awarded CMP support. This support is tied to distinct processing projects that are part of the students' graduate research portfolio. Since the first two students were supported with this new project-specific competitive process, we have issued three additional calls for proposals and awarded six additional support packages to PhD candidates. Two students awarded support from the May 2018 call have graduated, and we anticipate a call during the fall of 2019 to replace these students.

With each call, we are able to refine the requirements and the benefits of the CMP student support awards. The awards are reviewed and selected by a committee consisting of Bill Dunne, TCE associate dean for research and facilities, Chad Duty, MABE associate professor, Veerle Keppens, MSE department head, and Claudia Rawn, associate professor in MSE and CMP director.

In addition to supporting undergraduates participating in materials processing projects by covering wages for undergraduate research, the CMP has been providing matching scholarship funds for recruiting students into the field of MSE. Two of the original CMP/MSE scholarship recipients, recruited for outstanding performance either during Materials Camp or Governor's School for Science and Engineering, are thriving honors students in their third year with the MSE department. Another mode of supporting students is through the CMP covering initial membership dues for students to join Materials Advantage (MA). In FY19, seventeen student memberships ($30/student) were funded by the CMP; in subsequent years, the students are expected to pay for their own membership dues. The UT MA chapter gets a rebate of $5/member and $500 travel reimbursements for attending the MS&T and TMS annual meetings. The students become members in the American Ceramic Society, Association for Iron & Steel Technology, ASM International, and TMS. As part of the membership, the students receive rotating print and monthly electronic subscriptions of American Ceramic Society Bulletin, Iron & Steel Technology, Advanced Materials & Processes, and JOM.

Chris Wetteland continued in his position as the CMP associate director of industrial relationships and undergraduate research. During the last year, his efforts resulted in the recruitment of five new facilities level industrial memberships, which support students conducting materials processing related research. In recent years, the CMP completed the facilities level membership, which was designed to support Tennessee industries in need of processing and characterization support. The membership gives industry access to specialized processing and laboratory equipment. The rapid growth in memberships required the CMP to redirect resources to support this new initiative.

The support of MSE staff members continued to decrease due to a retirement in FY19; however, this staff member was recently (July '19) replaced by Gerald Egeland. Egeland's support is split between the CMP and the Department of Materials Science and Engineering with a synergistic mix of duties including acting as the MSE safety officer, supervising the MSE undergraduate laboratories, and overseeing CMP equipment for performing research related to CMP facilities memberships. The latter requires that Egeland works with both students and industrial representatives collecting a variety of data on CMP supported instruments pertinent to the industrial member's needs.

The CMP supported JIAM activities by providing partial support to JIAM Diffraction (XRD) Facility laboratory manager, Michael Koehler. Koehler is in charge of the day-to-day operations of the laboratory, which includes helping students and industry members in the collection and analysis of X-ray diffraction data. The facility is part of the University of Tennessee's Core Facilities Program. Koehler, Rawn, and Kurt Sickafus (JIAM Diffraction facility director and scientific leader) have been working together to expand the Diffraction Facility's user community and capabilities through the purchase of new hardware. Funding was acquired in late FY18 to purchase a cobalt X-ray tube. Copper X-ray tubes, previously the only type available at the JIAM Diffraction Facility, cause fluorescence in samples rich with iron or cobalt. This fluorescence resulted in increased noise and background in diffraction patterns, potentially hiding important details, such as small amounts of impurity phases. With the addition of the cobalt X-ray tube, users with samples that would normally suffer from fluorescence (e.g., steel samples) find the JIAM Diffraction Facility more accommodating. The JIAM Diffraction Facility served over 100 individual users from departments across UT. Students using the PANalytical X'Pert3 MRD and Empyrean X-ray diffractometers housed at the JIAM Diffraction Facility have carried out research studying radiation damage in materials, characterizing the atomic arrangement in materials with improved mechanical properties, and understanding how heat treatments can change additively manufactured parts. The CMP has also supported JIAM activities and works to increase the JIAM Core Facilities, both the diffraction and microscopy facilities, by covering some of the instrument usage charges for CMP supported students.

Another mechanism of supporting both graduate and undergraduate students while showcasing the JIAM was by the CMP co-sponsoring, with the Oak Ridge Chapter of ASM, their annual Educational Symposium. To learn more about this year's event, see page 23.

The CMP awards full or partial travel support to students who have won local CMP supported poster competitions; one event is held at the end of summer to showcase summer research, while another is held in the late fall in collaboration with the local chapters of larger professional societies, namely the Oak Ridge Chapter of ASM and the American Association of Crystal Growers, Southeast Section (AACG-SE). Top posters are recognized with travel support allowing student winners to attend professional meetings and present their research. These travel awards act as a way of disseminating the outstanding research by UT students to a larger community; the majority of travel funds were used in this manner. For more information on additional travel support, see page 22.

In FY19, the CMP supported the purchase of a NanoFlip testing system through the Scholarly Activity and Research Incentive Fund (SARIF) Equipment and Infrastructure Fund (Dayakar Penumadu, CEE professor). The equipment was cost shared with the Departments of Civil and Environmental Engineering, Materials Science and Engineering, Nuclear Engineering, and UT-ORNL Governor's Chairs Easo George and Steven Zinkle. The NanoFlip testing system is to be integrated at the JIAM Electron Microscopy user facility for obtaining material and interface mechanical properties at small length scales with the ability to simultaneously image using scanning electron microscopy. Carry over from FY18 and FY19 will be used to purchase a new Phenom ProX desktop scanning electron microscope (SEM) and a precision saw, to be housed in the undergraduate laboratories. The Phenom ProX desktop SEM, purchased by MSE, is five years old and sees heavy usage by both graduate and undergraduate students. With its mobility, it is often moved to recruitment events, such as the Engineering Fundamentals Fair. It is also a showcase instrument at recruiting events, including Engineers Day, Governor's School, and Materials Camp. The precision saw will also be housed in the MSE undergraduate laboratories and is a piece of equipment that MSE graduates are likely to use as engineers working in industry. Both the desktop SEM and the saw will be under the supervision of Egeland and Wetteland. Remaining funds will be used to match faculty requests to external and/or internal programs providing equipment funds.

The UT site of the Manufacturing and Materials Joining Innovation Center (Ma^2JIC), funded through the National Science Foundations (NSF) Industry/University Collaborative Research Center (I/UCRC) program, continues in Phase II along with The Ohio State University (the lead university site) and sites at Colorado School of Mines, Lehigh University, and the international site at the University of Waterloo (Canada). Rawn and Karen Boyce, CMP financial specialist, are both partially supported by the funds allocated for the administration of the UT site of Ma^2JIC. Ma^2JIC research interests that focus on materials joining, such as traditional welding and friction stir welding, are closely aligned with the CMP. Industrial support of the UTK Ma^2JIC site comes from EPRI, Miller Electric, NASA, U.S. Army Combat Capability Development Center (CCDC), and UT-Battelle. William Hamel, MABE professor, and his students work closely with staff members at the Manufacturing Demonstration Facility (MDF) through this program, with projects on adaptive welding for power plant piping and pressure vessels and large-scale additive metals manufacturing (LSAMM) with non-gravity aligned gas metal arc welding (GMAW). A supplement was just funded for supporting three undergraduate veterans in the MABE Department to perform research and attend the semi-annual Industrial Advisory Board (IAB) meetings. In June of 2020, the UT site will host the summer IAB meeting and a series of satellite meetings/workshops.

Community Outreach

Throughout the year, the CMP co-sponsors various activities supporting students' professional development. These activities range from introducing high school students to Materials Science and Engineering as a potential academic major and future career path to helping students travel and participate in professional conferences and training activities. Often the CMP partners with the Oak Ridge Chapter of ASM for both supporting student activities and co-sponsoring local professional events.

Materials Camp & Tennessee Governor's School

The CMP continued to support both these annual events. Materials Camp is a one-week camp experience introducing high school students to the field of materials science, where many of the CMP staff and supported students volunteer time mentoring the students. The support for Tennessee Governor's School is in the form of additional pay for a CMP graduate student to oversee a laboratory experience for some of Tennessee's brightest high school students to have a hands-on experience learning about ceramic synthesis.

MS&T 2018

In October, the CMP helped to cover some of the travel expenses for three MSE undergraduates to travel to the Materials Science and Technology (MS&T18) Technical Meeting and Exposition in Columbus, Ohio. During the week, the students attended both technical sessions and leadership activities. Travel support was also provided externally by a Materials Advantage MS&T travel grant.

TMS 2019

In March, the CMP helped to cover some of the travel expenses for two MSE teams to travel to the TMS 2019 Annual Meeting and Exhibition in San Antonio, Texas. Four of the students participated in the 2019 Materials Bowl competition and came in second. Other undergraduates participated in the Bladesmithing competition, a competition held every other year at the annual TMS meeting. This was the first time UT MSE students participated, and the team received a special citation for beauty for their blade, VOLSUNG.

Congressional Visit Days

Four students from the UT Materials Advantage Chapter participated in the Material Advantage Student Program's Congressional Visits Day (CVD) held in Washington, DC in early April. The CVD is an annual event where students are provided the opportunity to both learn about science, engineering, and technology funding and budgeting and to meet and educate legislators and staffers about how funding supports the students' professional development. Travel support was also provided externally to support the students' travel from Materials Advantage and the Student Organization Travel Fund Allocation.

Oak Ridge Chapter of ASM Educational Symposium

In May, the CMP was pleased to co-sponsor the Oak Ridge Chapter of ASM Educational Symposium on Residual Stress Determination Techniques for Science and Engineering at the Joint Institute for Advanced Materials. Nearly 50 participants, mostly students, were in attendance. Instructors for the one-day event included I. Cev Noyan (Columbia University), Jeff Bunn (Oak Ridge National Laboratory), Gary Schajer (University of British Columbia), and Seung-Yub Lee (Pratt & Whitney). They provided attendees with both a general introduction to basic mechanics and stresses and several methods of how to determine residual stresses along with associated errors and uncertainties.

Student Poster Competitions

At the end of the summer, the CMP hosts a poster competition allowing students to showcase the research they have been participating in during the summer. Later in the fall, the CMP then co-sponsors Student Night with the Oak Ridge Chapter of ASM. The CMP recognizes the students with the best posters by providing travel support, which allows the students to take their exceptional research results to larger, external audiences.

Student Night 2018

This annual event celebrating student research was held on October 25 at the Crescent Bend House and was co-sponsored by the Oak Ridge Chapter of ASM, the American Association of Crystal Growers, Southeast Section (AACG-SE), and the Center for Materials Processing (CMP). The evening featured research posters from 40 graduate students and eight undergraduates. Posters covered both experimental and computational studies, classes of materials studied included high entropy alloys and high entropy oxides, metals, ceramics, and plastics, and techniques used included friction stir welding, 3D printing, crystal growth, and laser synthesis. The AACG-SE, the Oak Ridge Chapter of ASM, and the CMP all recognized the top posters. The CMP matched most of the awards with equivalent travel support to be used by the students for presenting their work at professional conferences.

Future Goals and Plans

FY19 is promising to be an exciting year for the Center for Materials Processing. In September 2019, the CMP will be one of the Platium Sponsors of the Oak Ridge Chapter of ASM's 2019 Industry Night. The event brings together local industry, Oak Ridge National Laboratory research and development staff members, and faculty and students from the University of Tennessee's Department of Materials Science and Engineering. The CMP is also sponsoring eight undergraduate students to attend the MS&T 2019 Annual Meeting and Exhibition in Portland, Oregon, in October 2019. Seven of the students will be participating in the undergraduate student poster competition. Later in October, the CMP, the Oak Ridge Chapter of ASM, and the southeast section of the American Association of Crystal Growers will be co-sponsoring Student Night. Unlike the end of summer poster session, most of the poster contributions at this meeting are by graduate students.

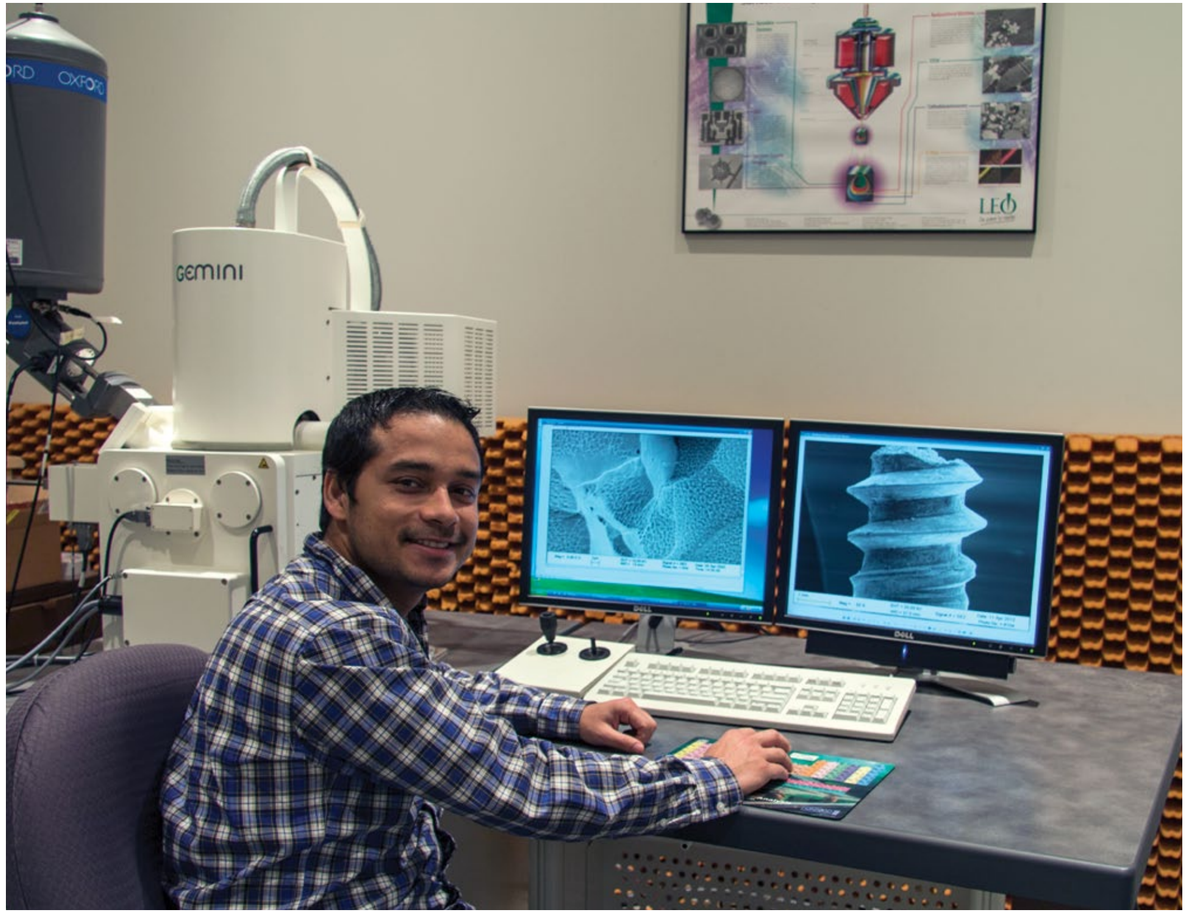
Goals again this year are for improving the CMP graduate support packages, increasing the number of graduate students receiving support through the competitive projects program, and increasing the number of facilities level memberships with local industry. We will build on our strong relationship with the Center for Industrial Services to support 10-15 new projects and to generate 3-5 new industrial memberships. CMP staff are working to make adjustments to the graduate student support packages to make them more attractive to both students and faculty advisors. Future support packages will likely include supporting JIAM Core facililty instrument usage funds and travel funds, to present the materials processing research at a professional technical meeting, in addition to stipend and health insurance support.

The CMP is also planning to purchase a second **Phenom ProX desktop SEM**. The current desktop SEM was purchased by MSE five years ago and has heavy usage by both graduate and undergraduate students as well as industrial partners. The new SEM will have significantly increased capabilities to support constituent groups. It is a cornerstone of recruitment activities and is showcased at recruiting events including Engineers Day, Governor's School, and Materials Camp. Because of its mobility, it is often moved to recruitment events like the Engineering Fundamentals Fair held in the fall and spring semesters where first-year students explore the various majors.

CMP Equipment

The CMP owns a variety of equipment which is used by undergraduate students, graduate students, and industrial contacts through CMP membership agreements. Instruments are located on the UT campus (Dougherty Engineering Building) and Cherokee Farms at the Joint Institute for Advanced Manufacturing (JIAM). A full list of CMP equipment can be found at ***https://cmp.utk.edu/catalog-of-experimental-equipment/***. The website includes links that provide equipment capabilities and describe procedures for reserving instrument time.

One such instrument is the INSTRON Universal Testing Machine with a 10 kN load cell. Located in Dougherty 601, the INSTRON Universal Testing Machine is primarily used for tensile and bend testing of polymers and composites but can test metals with restricted cross-sections. Recently, Minifibers of Johnson, Tennessee, performed a series of tensile tests for exploring the flexibility of asphalt emulsion films with and without the incorporation of fibrillated high-density polyethylene fiber. Bruce Prezzavento, the technical director for Minifibers, states that, "Over a period of a few months, MSE students propelled the project forward by providing preliminary INSTRON test results of specimens made in our laboratory. Along with access to the instrument and the time provided by the students, the department also made available materials science faculty members who provided guidance in the development of the experimental design of the investigation. When all is said and done, this collaboration truly represents the kind of cooperation that fuels Tennessee research capability, both in manufacturing and in education."



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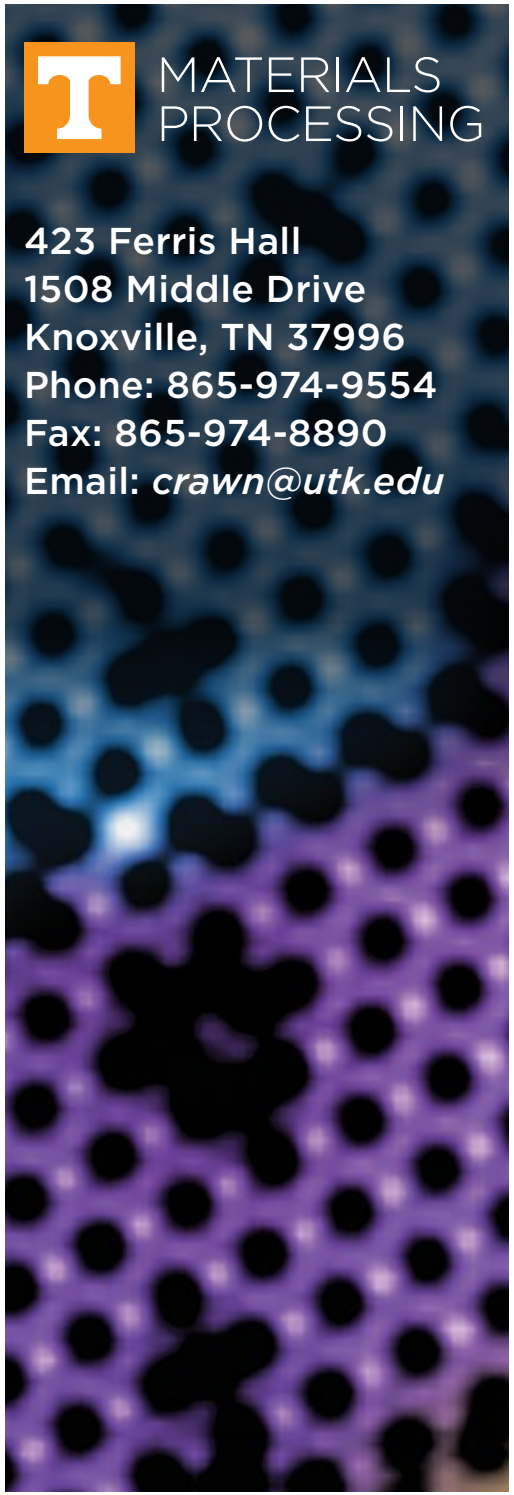

MATERIALS PROCESSING

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